RF and Field Profile Measurements of Gun 3.2 on July 30th, 2008

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Measurement Lists

1. Measure and define some important RF parameters for pi-mode and 0-mode

⇒ Resonant frequency
⇒ Operating temperature
⇒ Reflection coefficient (S11)
⇒ Quality factor (Q-factor)

Environmental conditions affecting to resonance frequency:

- Different between measured temperature (T_{room}) and operating temperature (T_{op}) → ΔT
  ⇒ leading to frequency shift df/dT~ -22 kHz/degree
- Different between measured pressure (P_{air}) and operating pressure (P_{vac})
  ⇒ can be defined by the dielectric constant ε_r
  ⇒ results in frequency shift of Δf = +390 kHz

$$f_0 \,\alpha\, \frac{1}{\sqrt{\varepsilon_r}} \quad \Rightarrow \quad \Delta f_\varepsilon = f_{op}(\sqrt{\varepsilon_{air}} - 1)$$

The resonant frequency (f_0) scaling law including frequency shifts from temperature and pressure effects

$$f_o = f_{op} - \frac{df}{dT} \cdot \Delta T - 390\,kHz$$

2. To measure longitudinal field profile and define the ratio of the field at the cathode and at the middle of the full-cell

Longitudinal field profile and field ratio measurements

Measuring of the longitudinal field profile by using the theoretical idea of

Slater's Perturbation:

$$\frac{\Delta\omega}{\omega} = \frac{\Delta U_M - \Delta U_E}{U} = \frac{\int_{\Delta V} (\mu H^2 - \varepsilon E^2) dV}{\int_V (\mu H^2 + \varepsilon E^2) dV}$$

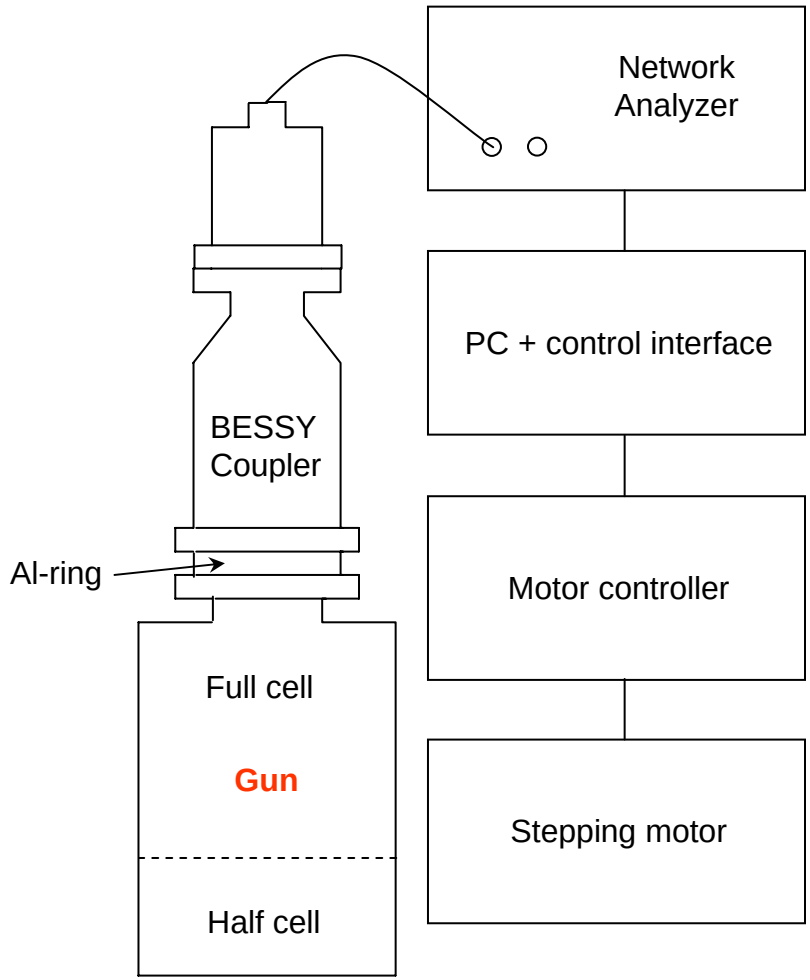
Resonant frequency shift

$$\downarrow$$

$$E_z \; \alpha \; \sqrt{\Delta\omega} = \sqrt{f - f_0}$$

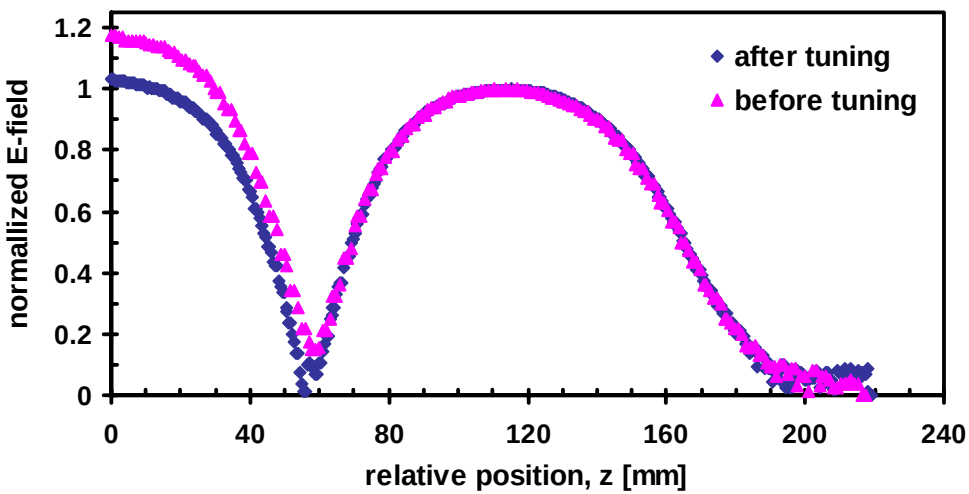
Field balance (FB) $\rightarrow \frac{E_{fullcell}}{E_{cathode}}$

Bead pull measurements have been performed using stepping motor and PC interface (LabView).



Results of RF measurements of gun 3.2 before installation at PITZ

Date	Conditions	Setup	f (GHz)	S_{11} (dB)	FB	Q_0	T_{op} (°C)	Δf_c (kHz)	$\Delta f_{0-\pi}$ (MHz)
24.10.2006	Before tuning (air, 24°C)	Mo-cathode + hole + BESSY coupler	pi: 1.301 338 0: 1.296 339	- -	1.18 1.58	- -	102 -	- -	5.0
24.10.2006	After tuning (air, 24°C)	Mo-cathode + hole + BESSY coupler	pi: 1.300 315 0: 1.295 173	-26 -9	1.03 1.88	21316 14078	56 -	- -	5.1
08.01.2007	Water pipes fixed (air, 21°C)	Mo-cathode + BESSY coupler	pi: 1.300 470 0: 1.295 338	-32 -11	- -	20800 13402	60 -	- -	5.1
15.02.2007	PITZ1.6 (air, 26°C)	No cathode + FEL-4 coupler	pi: 1.300 688 0: 1.295 705	-21 -12	- -	23853 -	75	- -	5.0
	PITZ1.6 (air, 26°C)	Calculate for setup with cathode	pi: 1.300 438	-	-	-	64	~250	



Electric field profiles for pi-mode of gun 3.2 before and after tuning (measured on October 24th, 2006) .

Comparison of RF measurement results of gun 3.2

Date	Conditions	Setup	f (GHz)	S_{11} (dB)	FB	Q_0	T_{op} (°C)	Δf_c (kHz)	$\Delta f_{0-\pi}$ (MHz)
24.10.2006	After tuning (air, 24°C)	Mo-cathode + hole + BESSY coupler	pi: 1.300 315 0: 1.295 173	-26 -9	1.03 1.88	21316 14078	56 -	- -	5.1
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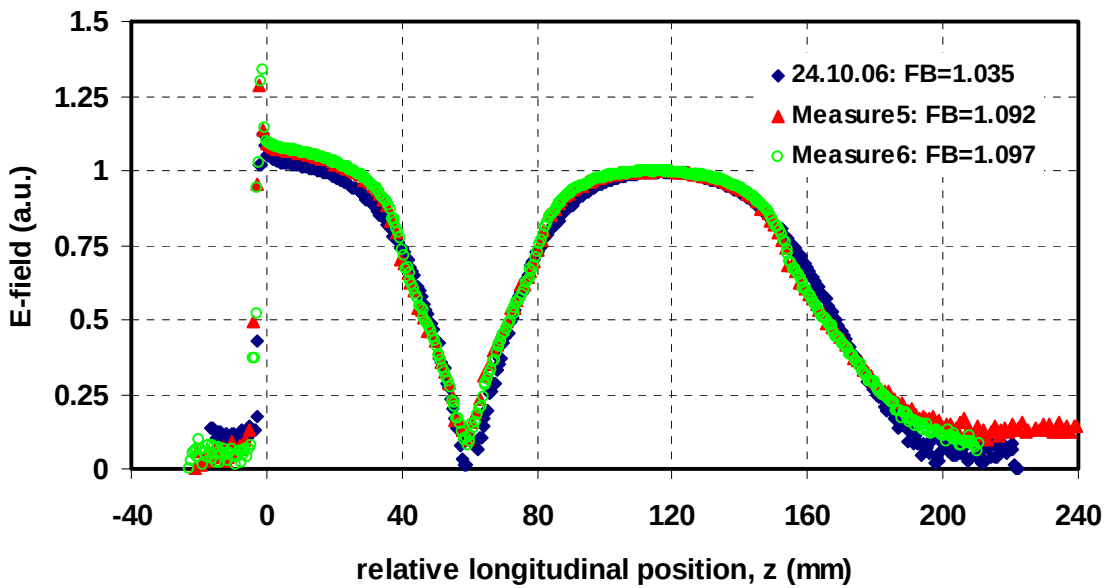
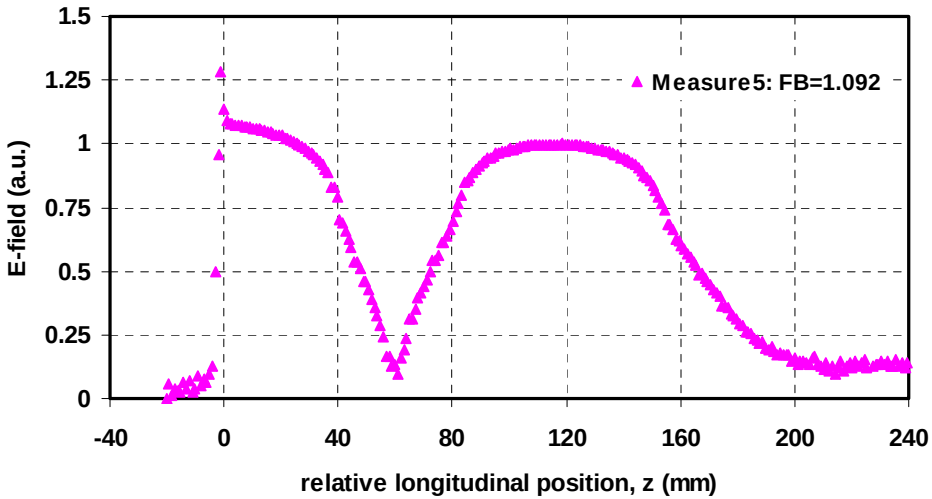
15.02.2007	PITZ1.6 (air, 26°C)	Calculate for setup with cathode	pi: 1.300 438	-	-	-	64	~250	
30.07.2008	After dissemble from PITZ1.6	Mo-cathode + hole + BESSY coupler	pi: 1.300 463 0: 1.295 413	-21.4 -9.3	1.09-1.10 1.71	25081 16565	64.3 -	247 -	5.05 -



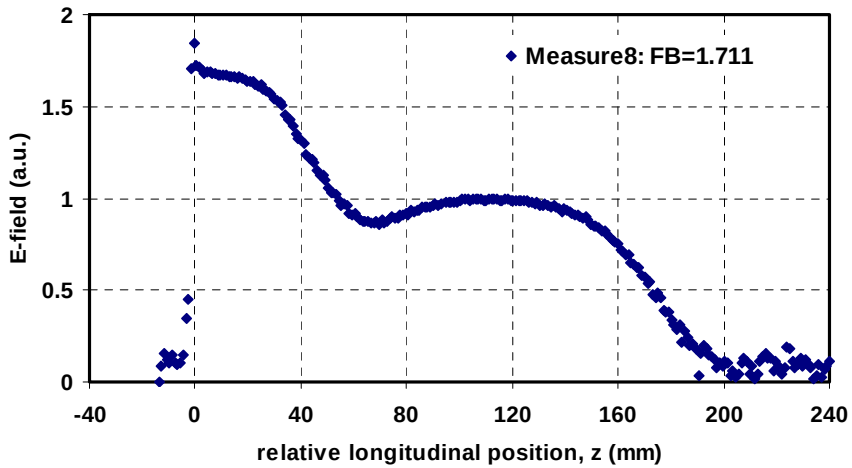
Comparison of electric field profiles for pi-mode of gun 3.2 on October 24th, 2006 and July 30th, 2008.

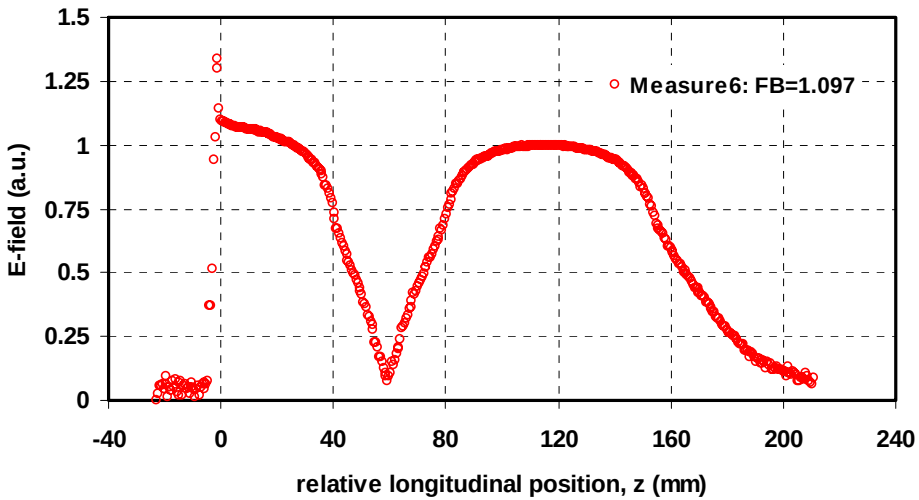
Bead-pull measurement results on July 30th, 2008

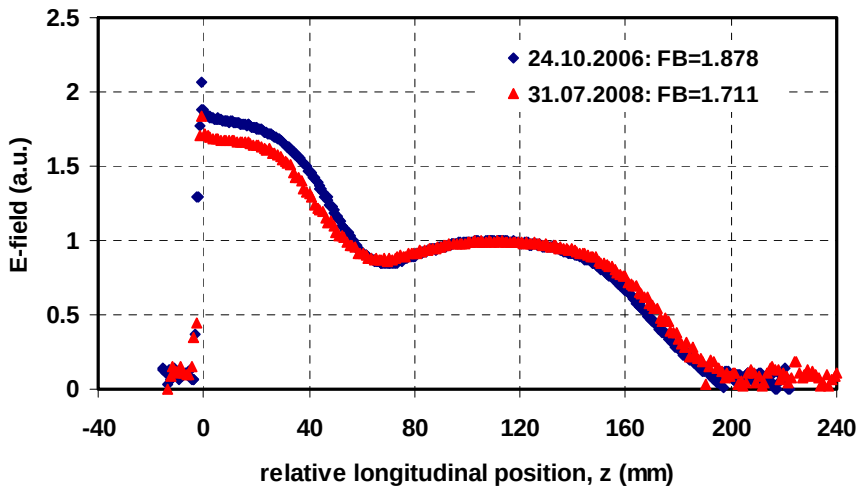
Electric field profile of the gun 3.2 for π-mode



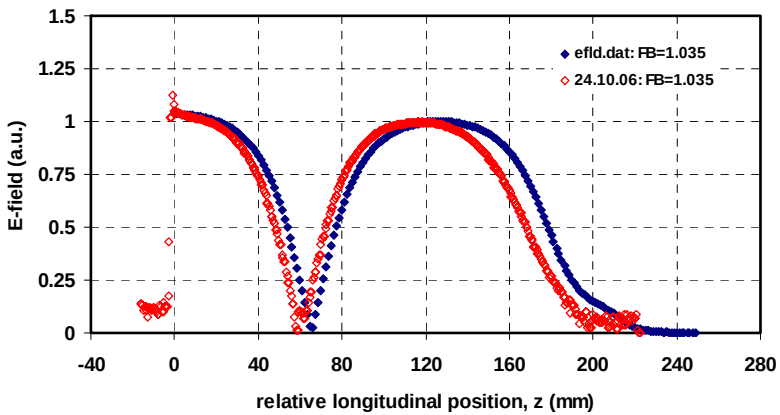
Electric field profile of the gun 3.2 for 0-mode

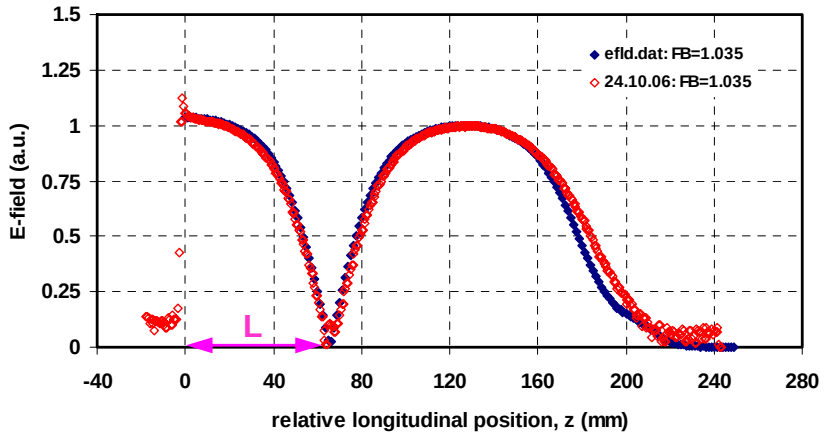




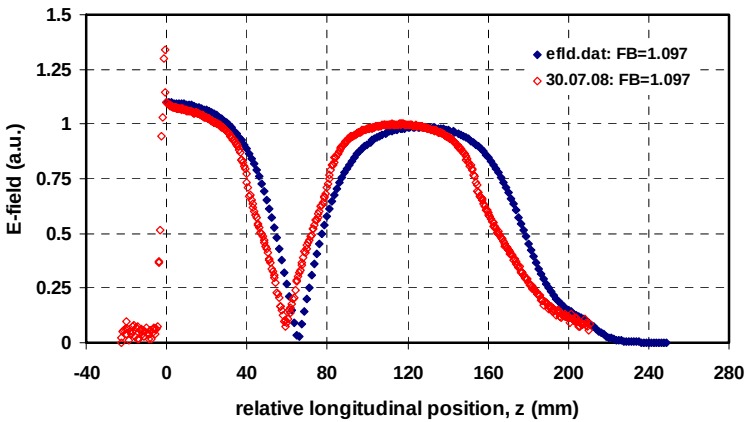


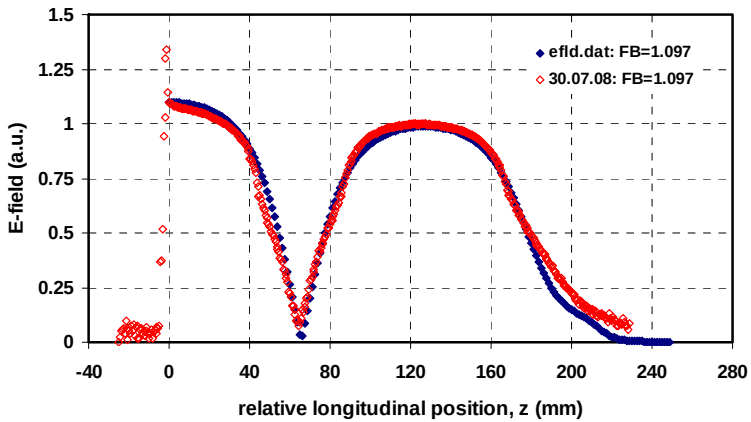
Comparison of field profiles with efld.dat and scaled length using the half-cell iris position





L: length of half-cell for efld.dat = 65 mm





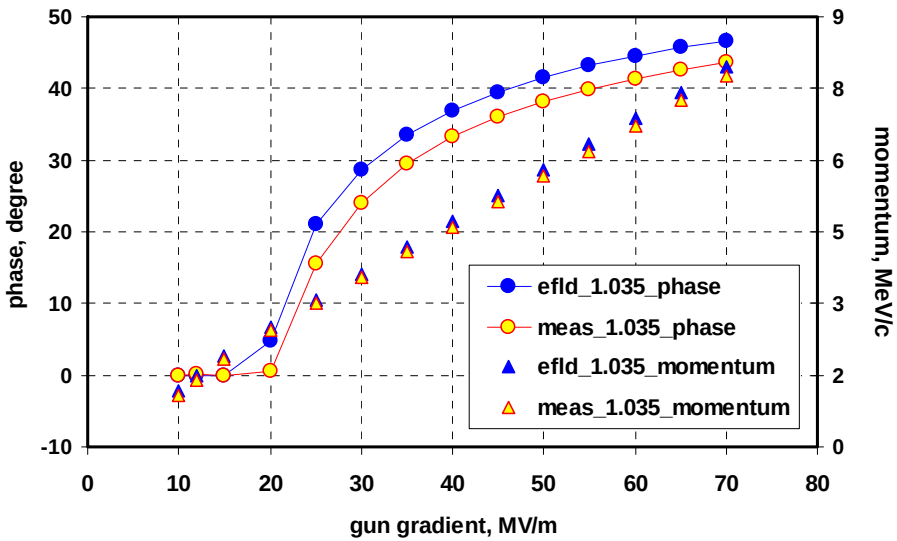
- **Scale factor for adjusting the field profile of the measured data on 24.10.2006 to fit with efld.dat = 59.39 mm**
- **Scale factor for adjusting the field profile of the measured data on 30.07.2008 to fit with efld.dat = 59.94 mm**
- **The difference length of the half-cell from the out put of bead-pull program between October 24th, 2006 and July 30th, 2008 = 0.55 mm (Motor factor = 0.19679)**

Astra simulation results

Simulation parameters:

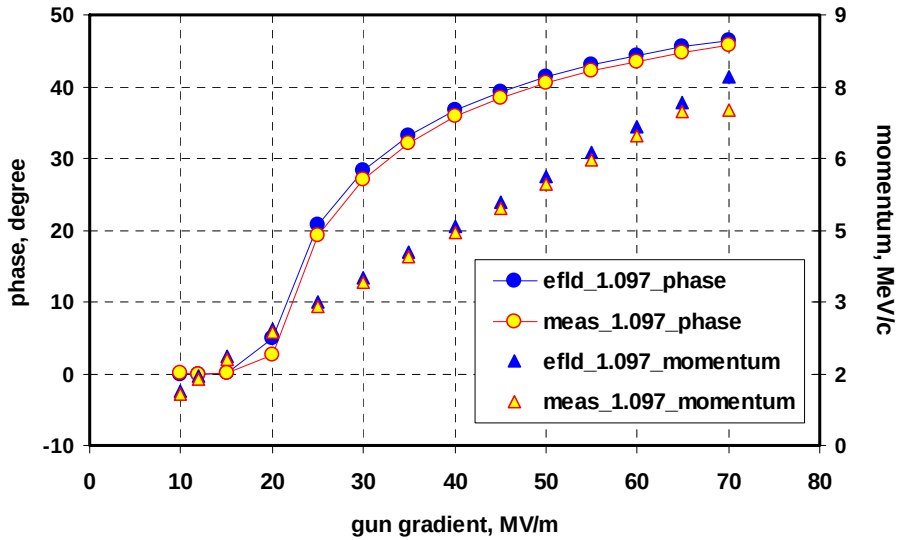
- Laser: 20 ps (FWHM), rise/fall time = 6.5 ps, XYrms=0.4205 mm
- 1 nC bunch charge
- Main solenoid current = 360A with bucking solenoid compensate
  (From Astra results, the solenoid current does not effect to the optimum phase and momentum)
- Auto phase by Astra

Simulation results for FB=1.035



@ 60 MV/m, Δphi~3.3 degree, Δp~0.16 MeV/c

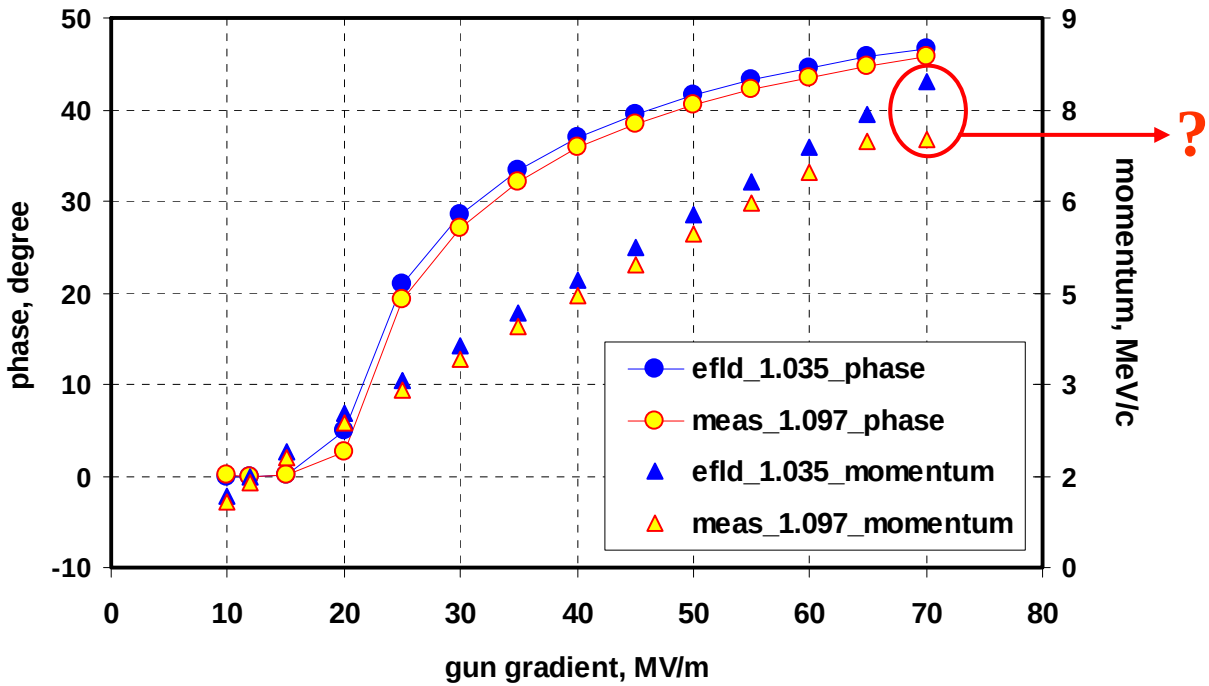
Simulation results for FB=1.097



@ 60 MV/m, Δphi~0.8 degree, Δp~0.17 MeV/c

Astra simulation vs. gun condition during the measurement period at PITZ1.6 in summer 2006

Comparison of the simulation results for typical Astra efld.dat (FB=1.035) and measured field on July 30th, 2008 (FB=1.097)



@ 60 MV/m, Δphi~1.1 degree, Δp~0.38 MeV/c ⇒

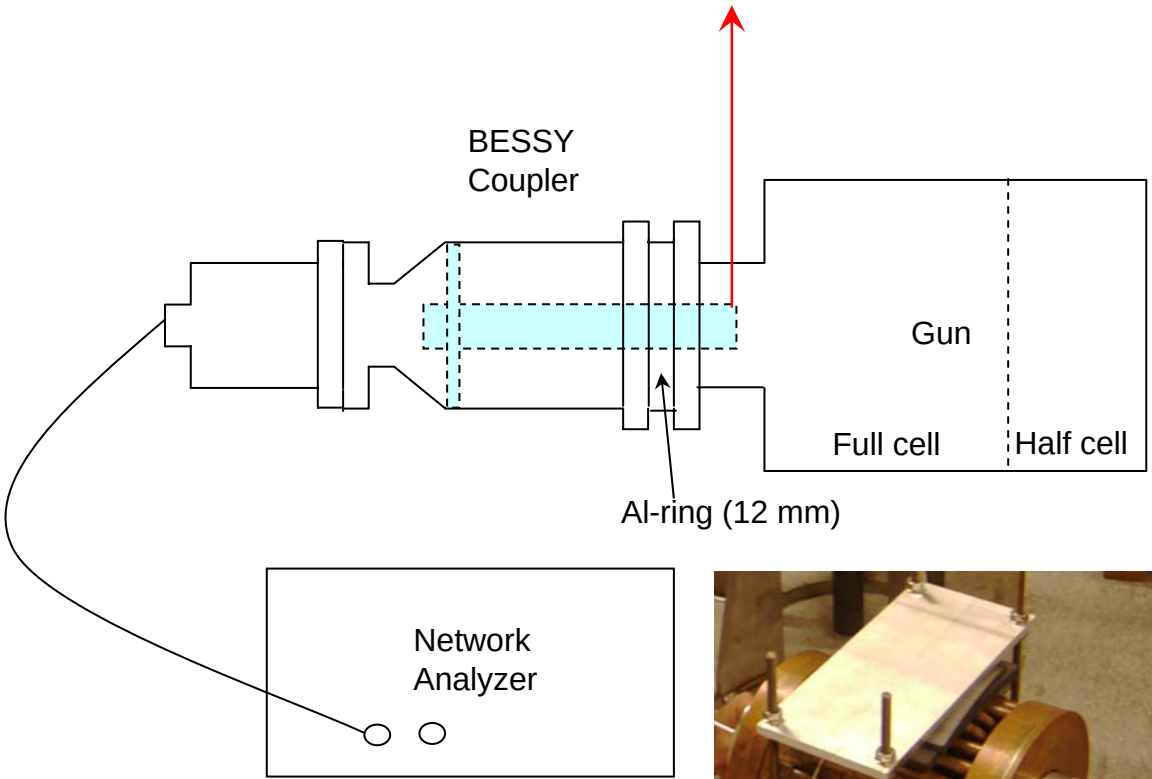
Did we see similar results in our measurements?

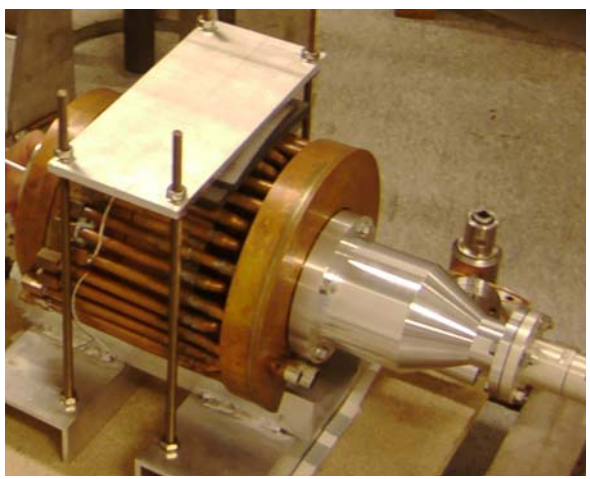
↓

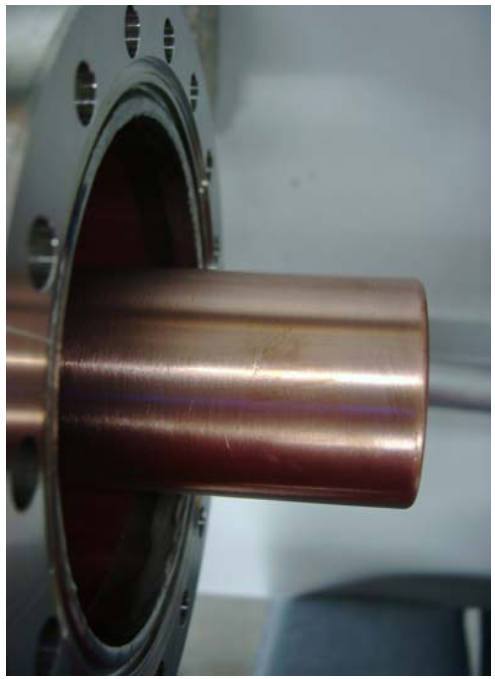
No, we see the different of optimum phase about 5º between the Astra and measurement results (Ref: J. Rönsch)

Effect of coupler position (1)

The position of cylindrical shell in the coupler affected to the resonant frequency, reflection coefficient (S_{11}) and field profile in the gun cavity.



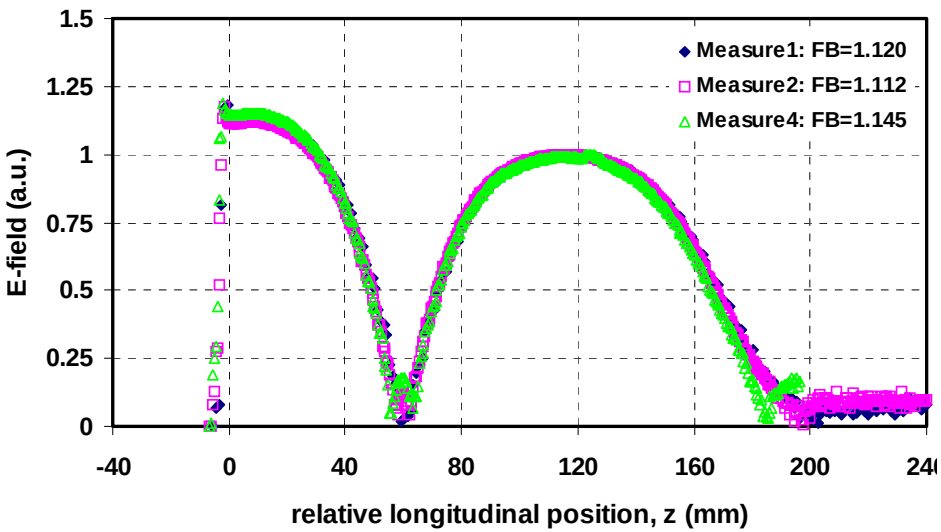


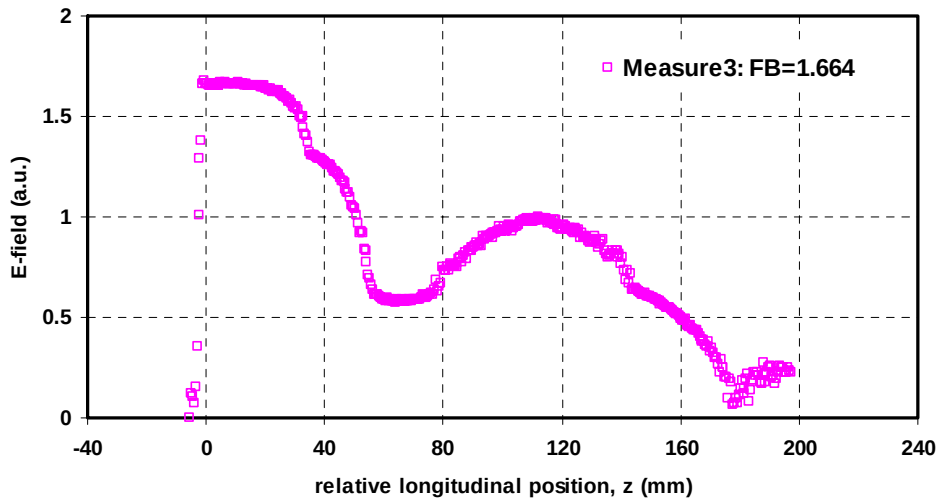


FEL-4 coupler (typical coupler for gun cavity at PITZ)

Effect of coupler position (2)

Setup	f (GHz)	S_{11} (dB)	FB	Q_0	T_{op} (°C)	$\Delta f_{0\text{-}\pi}$ (MHz)
Before adjusting coupler	pi: 1.300 500 0: 1.295 401	-17 -20	1.11-1.12 1.66	19823 -	66 -	5.1
After adjusting coupler	pi: 1.300 463 0: 1.295 413	-21.4 -9.3	1.09-1.10 1.71	25081 16565	64.3 -	5.05 -





Longitudinal field profile for pi-mode (left) and 0-mode (right) before adjusting the coupler position

Conclusion

• RF parameters (resonant frequency, reflection coefficient, Q-factor) of the gun 3.2 before installation and after dissemble from PITZ1.6 did not significantly change (Δf=+25 kHz, ΔS_{11}=-4.6 dB, ΔQ=+3765)

• Field balance of the gun 3.2 which measured after the gun was dissembled from PITZ1.6 was about 6% higher than before installation at PITZ

• Simulations for the Astra field profile (efld.dat) and the measured field profile for different gun gradient showed comparable results

• Installation and alignment of the gun coupler may effect to the RF parameters and field profile of the RF gun